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A REMOTELY OPERATED MULTIPLE ARRAY ACOUSTIC RANGE (ROMAAR) AND ITS APPLICATION FOR THE MEASUREMENT OF AIRPLANE FLYOVER NOISE FOOTPRINTS

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November 1976

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16. Abstract

The ROMAAR now in operation at NASA will allow direct measurement and display of aircraft noise in several measurement units during takeoff, landing, and flyby operations. This information, in addition to its application in terms of ground noise footprints, will also permit determination of the statistical variation of footprints or contours due to the atmosphere or aircraft operational parameters, a measure of the impact of various noise reduction techniques and hardware on ground noise footprints, and the ability to supply direct inputs for improvements of the NASA Aircraft Noise Prediction Office predictive program. The methods, techniques, and equipment developed for the ROMAAR concept are applicable to CTOL, STOL, General Aviation, and VTOL aircraft. ROMAAR represents a unique combination of state of the art digital and analog noise recording methods, computer-controlled digital communications methods, radar-tracking facilities, quick-look weather capabilities, and a large data handling facility complemented by a large capacity curve fitting and plotting routine. The ROMAAR is set apart from the standard airport noise monitoring system by having the unique features mentioned above plus the fact that at present as many as 38 separate (but simultaneous) noise measurements can be made for each aircraft overflight. This paper will present a brief description of the ROMAAR facility and its uses along with an example of some actual measurements which demonstrate its application to ground noise footprints.

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noise footprints, radar-tracking facilities, monitoring system

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ABSTRACT

The ROMAAR now in operation at NASA will allow direct measurement and display of aircraft noise in several measurement units during takeoff, landing, and flyby operations. This information, in addition to its application in terms of ground noise footprints, will also permit determination of the statistical variation of footprints or contours due to the atmosphere or aircraft operational parameters, a measure of the impact of various noise reduction techniques and hardware on ground noise footprints, and the ability to supply direct inputs for improvements of the NASA Aircraft Noise Prediction Office predictive program. The methods, techniques, and equipment developed for the ROMAAR concept are applicable to CTOL, STOL, General Aviation, and VTOL aircraft. ROMAAR represents a unique combination of state of the art digital and analog noise recording methods, computer-controlled digital communications methods, radar-tracking facilities, quick-look weather capabilities, and a large data handling facility complemented by a large capacity curve fitting and plotting routine. The ROMAAR is set apart from the standard airport noise monitoring system by having the unique features mentioned above plus the fact that at present as many as 38 separate (but simultaneous) noise measurements can be made for each aircraft overflight. This paper will present a brief description of the ROMAAR facility and its uses along with an example of some actual measurements which demonstrate its application to ground noise footprints.

INTRODUCTION

The Remotely Operated Multiple Array Acoustic Range (ROMAAR) has been developed to directly measure and display aircraft noise in several measurement units during takeoff, landing and flyby operations. Use of the ROMAAR will improve the understanding of basic noise propagation and the effects of the atmosphere and other variables and will also be of value in assessing the impact of noise reduction technology on the community. The ROMAAR represents a unique combination of state of the art digital and analog noise recording methods, computer-controlled digital communication methods, radar-tracking facilities, quick-look weather (profile) capabilities, and a large data handling facility complemented by a large capacity curve fitting and plotting routine.

This paper will present a brief description of the ROMAAR facility and its uses along with an example of some actual measurements which demonstrate its application to ground noise footprints.

APPLICATIONS OF ROMAAR

The ROMAAR will have applications in several major research areas including the evaluation of prediction methods currently being used by the NASA's Aircraft Noise Prediction Office (ANOPO), of various aircraft configurations and operating procedures, and investigating the effects of the atmosphere on ground noise measurements,

in particular, their application to ground noise footprints. The ROMAAR provides for multiple microphone locations which allows for noise measurements at many locations during the flyover of an aircraft for source noise research, one-on-one predictive schemes, or the direct measurement of noise data necessary for the development of noise contours. It is the latter feature, the measurement of noise data for contour definition that will be briefly discussed in the present paper. The schematic of figure 1 illustrates, in a simplified manner, the concept of noise contours or footprints. The boundary or contour line is simply a line of constant noise level that can be traced on the ground during an aircraft flyover operation. The shading simply indicates varying levels of noise exposure. Contours such as these are useful in evaluating the effects of noise reduction techniques, the intrusion of noise on communities surrounding airports, etc.

THE ACOUSTIC RANGE

In order to accomplish flyover noise testing in general, there are certain desirable characteristics that an acoustic range must have. Ideally, an acoustic range would need to be situated in an area where ambient noise is low, and the area should not be overflown routinely by aircraft other than the one under test. In order to correct the acoustic data for aircraft position and weather differences, one needs aircraft tracking facilities and weather observation facilities

that ideally would provide not only ground level and ten meter measurements but also profile-type measurements utilizing balloons, instrumented aircraft, or other means. The availability of relatively flat, open areas for the location of microphone arrays is also a requisite to minimize shielding, reflection, shadow zones, etc.

The NASA Wallops Flight Center on the eastern shore of Virginia, figure 2, essentially provides all of these desirable features. The insert in the figure is an aerial photograph of the airfield at Wallops Flight Center. It can be seen that the terrain surrounding the airfield is flat and open.

The general ROMAAR concept is shown as an artist's concept in figure 3 where the basic elements of acoustic measurements, radar tracking, and weather facilities are indicated along with the appropriate airfield support facilities. More specifically, these elements are: noise measurements consisting of analog stations (manned) and digital stations (unmanned); aircraft position determined by radar; aircraft operating parameters from on board recorders, time correlation from WWVB and weather measurements including those made at 1.2 meters, 10.0 meters, and up to the aircraft test altitude using tethered and free balloons.

The present paper will describe only the noise measurement and data handling features of ROMAAR.

ELEMENTS OF NOISE MEASUREMENT

The noise measurement portion of the ROMAAR range is comprised of 20 remotely operated digital (unmanned) acoustic measurement stations that are capable of supplying digital representation of an overall time history, a dB(A) time history, or a dB(D) time history. In addition to the 20 remote units which are operated by a sequencing network and controller built around VHF radio communication techniques, there are 6 manned instrumentation vans utilizing analog recording capabilities and each have three microphone systems for a total of 18 microphones that supply complete spectra data as necessary.

Digital Noise Measurement System

As indicated in the schematic to the left of figure 4, the digital noise measurement system is comprised of a standard Bruel and Kjaer outdoor microphone system whose output is fed to a Bruel and Kjaer digital tape recorder. This system records data on magnetic tape in digital form using a half-second sample rate. The system is time correlated and synchronized with a WWVB time signal which is recorded on digital tape and forms part of the tape header information prior to each test sequence (flyover). At this time, the microphone system is calibrated through an electrostatic actuator, and the value is recorded on tape as part of the tape header information. This complete sequencing network is initiated and controlled by techniques utilizing a VHF Motorola/Engineered Systems, Inc., transceiver built into the system. The whole system is battery operated and is completely self-sustaining. On the right side of the figure is shown a photograph of typical installation in the field. The units are located in open areas, and the two

are separated; that is, the front end or sound measuring equipment and the recording equipment. Steps have been taken to protect the units from the weather and vandalism.

Analog Noise Measurement System

Shown schematically at the left of figure 5 is an analog noise measurement and recording system. This system is made up of standard commercially available condensor microphone equipment and following amplifiers widely accepted by industry for noise measurements, including aircraft noise certification. The microphones can be located up to 1,500 feet away from the van. The output of the microphone system is recorded in the analog form using FM recording techniques. This system also includes a time code generator synchronized to WWVB, whose output is recorded on one channel of the magnetic tape. This allows for time correlation with all other stations in the system. As indicated in the photograph at the right of the figure, this equipment is physically contained in this van arrangement. This mobile van is powered by a small gasoline driven generator and is completely self-sufficient. The van operator has a radio which is tied into the controller/sequencing network.

Noise Measurement Locations

For the initial operation of the ROMAAR, the digital and analog systems were located as shown in figure 6. This particular deployment was chosen based on landing approach operations and cover an area approximately 5 miles in length and approximately 1-1/2 miles in width.

Figure 7 is a photograph of one of the microphone locations in the ROMAAR facility. Most of the locations are similar to the one shown. In the selection of station locations, an attempt was made to locate them in flat, open areas away from trees and other obstructions and away from other noise sources such as traffic. The exact geographic locations of each measurement point have been located with a very high degree of accuracy using standard land and aerial survey methods.

ROMAAR Central Station

All measurement stations are controlled from the central station complex as shown in figure 8. To the left of the figure is a system schematic that indicates that the digital system can be controlled either by a computer or manually by a central station operator. The digital stations can be started, stopped, calibrated, etc., from this location. In addition, a complete communications network is established between this central station and the operators of the analog stations, the control tower, the radar facilities, and all other facilities whose activities are necessary to support the operation of the range.

DATA FORMATTING AND PROCESSING

Following an actual flight operation, the acoustics data, in digital and analog form as acquired by the previously describing noise systems, along with information concerning the aircraft operations and position, and weather information, are returned to the Langley Research Center for formatting and processing. The flow diagram for this process is shown schematically in figure 9. The data can be corrected for

weather and aircraft positional errors, and various noise descriptors such as overall sound pressure level, dB(A), or dB(D), can be either directly read or computed, depending on whether it originated at a digital or an analog station. The description is listed for the geographical location of each microphone station by flight number and then used as inputs to a plotting routine using a computer. The output of this plotting routine can be in the form of ground noise footprints.

INITIAL ROMAAR OPERATIONS

After installation of the noise measurement portion of the ROMAAR and prior to its actual operation in support of a research project it was necessary to perform a functional evaluation.

Functional Evaluation

This test consisted of a series of flyovers utilizing a Langley Research Center based T-38A jet aircraft. Analog and digital measurement stations were co-located at several locations within the range both on the flight track and laterally deployed, and the measured descriptors were compared. In figure 10 are presented the comparison max dB(A) and time of occurrence from three stations, all located along the track. Inspection of the data indicate good agreement. It is of interest to note that the noise levels at the other stations were also in good agreement.

T-38 Landing Approach Operations

Following the functional evaluation of ROMAAR, a series of 3° landing approaches using the T-38A were accomplished. The purpose of these flights was to obtain the data necessary to demonstrate that landing approach noise footprints could be constructed from the ROMAAR measurements. The noise measurement stations were redeployed to the locations as indicated in figure 6 for this series of tests.

For each landing approach of the aircraft, a maximum dB(A) number was recorded at each noise measurement station. The data from one of these flights is shown in figure 11. In this figure, the solid symbols indicates the station locations along the ground track. The numbers represent the maximum dB(A) level measured at each station location during the flight. For purposes of clarity the vertical scale (lateral distance) and the horizontal scale (distance along the flight track) are different. Also shown in figure 11, for comparative purposes, is a predicted 80 dB(A) contour for the T-38A aircraft. It should be noted that no corrections have been made to the measured data to account for aircraft position errors or effects of weather. The predicted contour is shown simply to illustrate one of the applications of ROMAAR--to allow direct comparison of an experimentally determined data with that calculated used current predictive schemes.

Utilizing the set of measured data as shown in figure 11, a best fit line which represents the 80 dB(A) and the 90 dB(A) contours are drawn thru the data points and are shown in figure 12.

By inspection, one can see that the contours constructed from the measured data have the same general shape as the predicted one shown in the previous figure. The measured contours are not axisymmetric, however, which could be attributed to the effects of weather and aircraft position.

This series of landing approach measurements served to demonstrate that the range was truly operational.

CONCLUDING REMARKS

This paper has provided a brief overview of the Remotely Operated Multiple Array Acoustic Range (ROMAAR) including information on its basic elements, but with particular emphasis on the acoustic measuring system. Descriptions of the data formatting and analysis techniques utilized in ROMAAR have been presented along with some initial results of ground noise footprints obtained from actual noise measurements utilizing ROMAAR.

The methods, techniques and equipment developed for the ROMAAR concepts are applicable to CTOL, STOL, General Aviation, VTOL aircraft. ROMAAR represents a unique combination of state of the art digital and analog noise recording methods, computer-controlled digital communications methods, radar-tracking facilities, quick-look weather capabilities, and a large data handling facility complemented by a large capacity curve fitting and plotting routine. The ROMAAR is set apart from the standard airport noise monitoring system by having the unique features mentioned above plus the fact that at present as many as 38 (simultaneous) noise measurements can be made for each aircraft overflight.

The ROMAAR which is now in operation at the NASA's Wallops Flight Center, allows the measurement of noise at a large number of positions on the ground and in a number of measuring units during takeoff, landing, and flyby operations of aircraft. This information, in addition to its application to the development of ground noise footprints, will also provide information as to the statistical variations of noise as a result of variation in the atmosphere, for variations in aircraft operational procedures, a measure of the benefits associated with various noise alleviation devices and to provide basic noise inputs to be utilized in the NASA Noise Prediction Office predictive program.

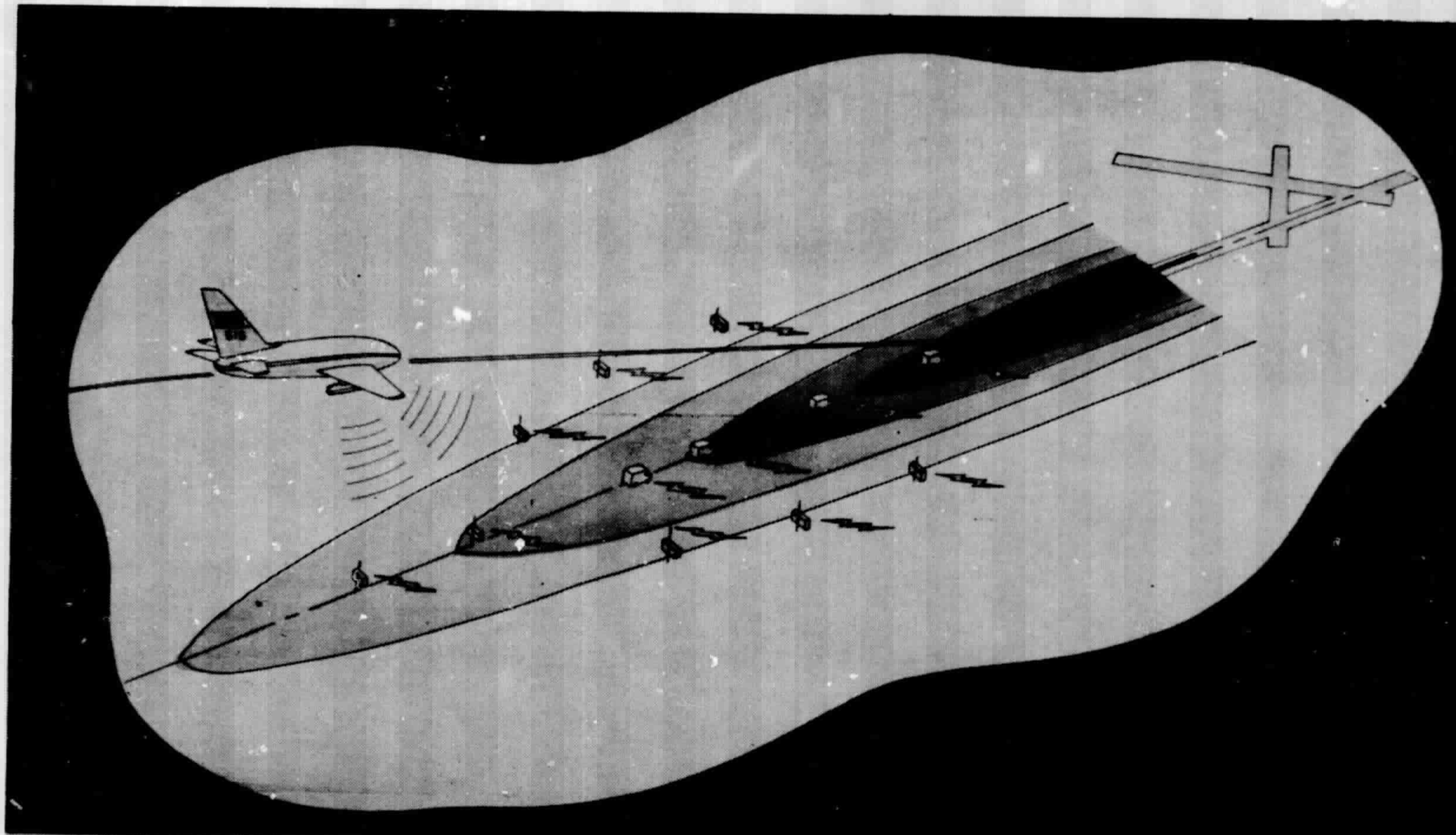


Figure 1. - Schematic Illustration of Ground Noise Contours or Footprints

Figure 2.- Wallops Flight Center Test Area

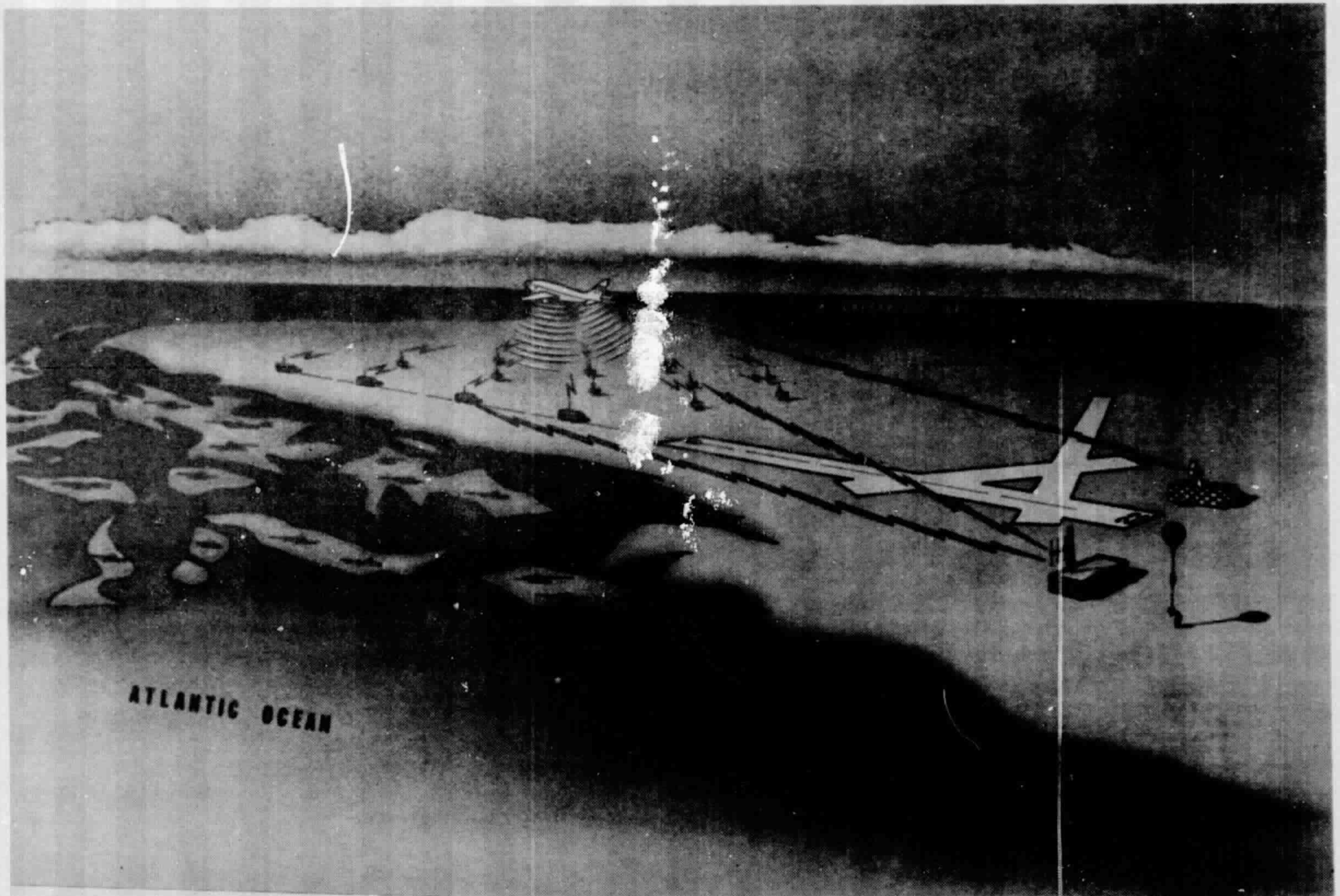


Figure 3. - Schematic Illustration of the ROMAAR Concept

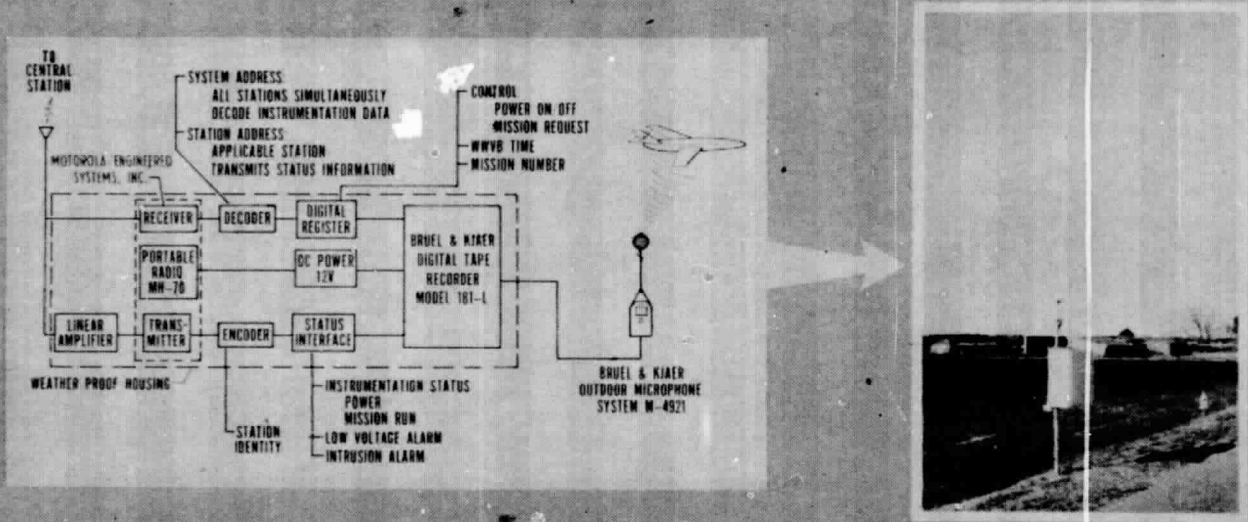


Figure 4. - Schematic and Photograph of the Digital Noise Measurement System.

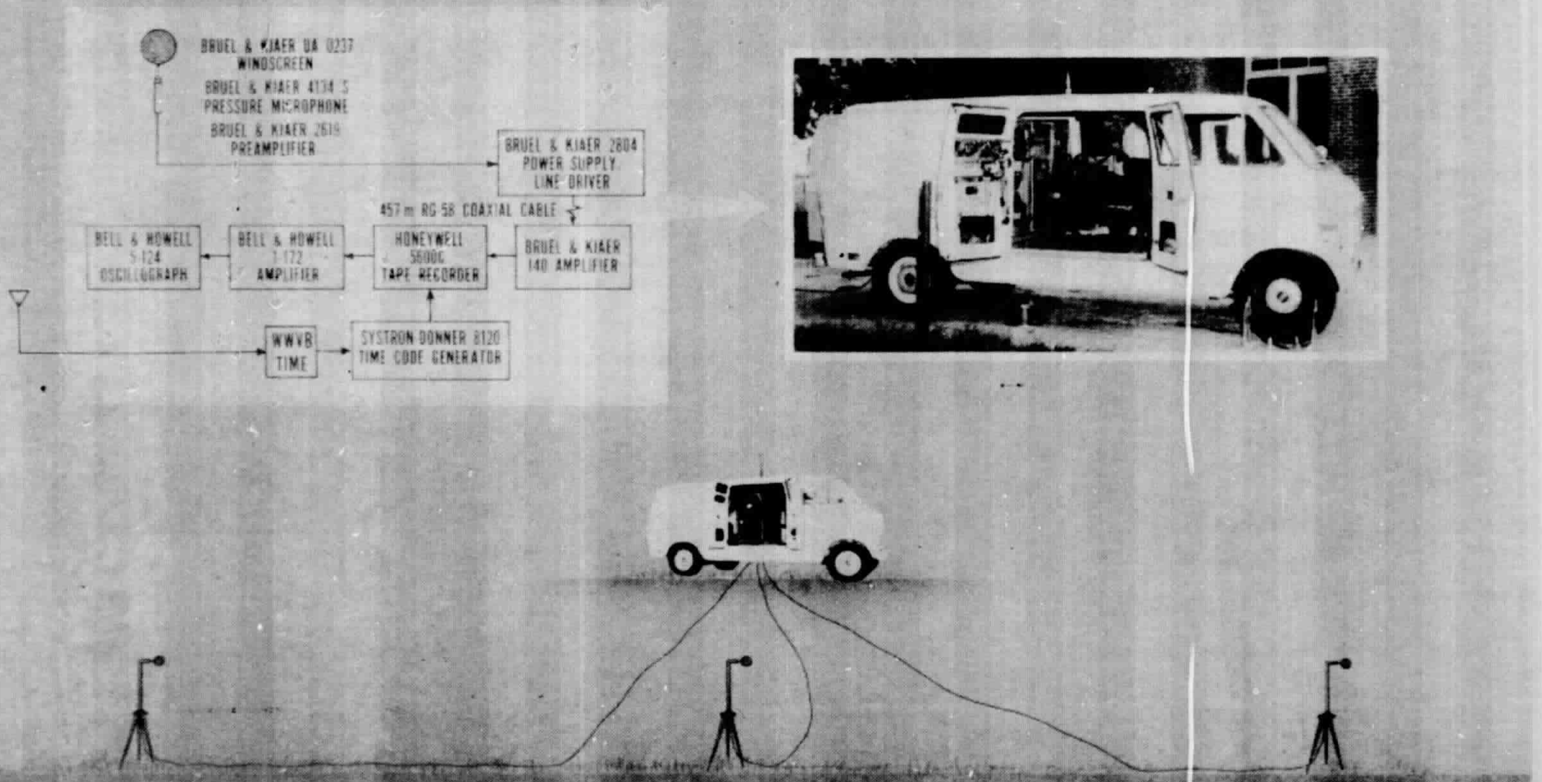


Figure 5. - Schematic and Photograph of the Analog Noise Measurement System.

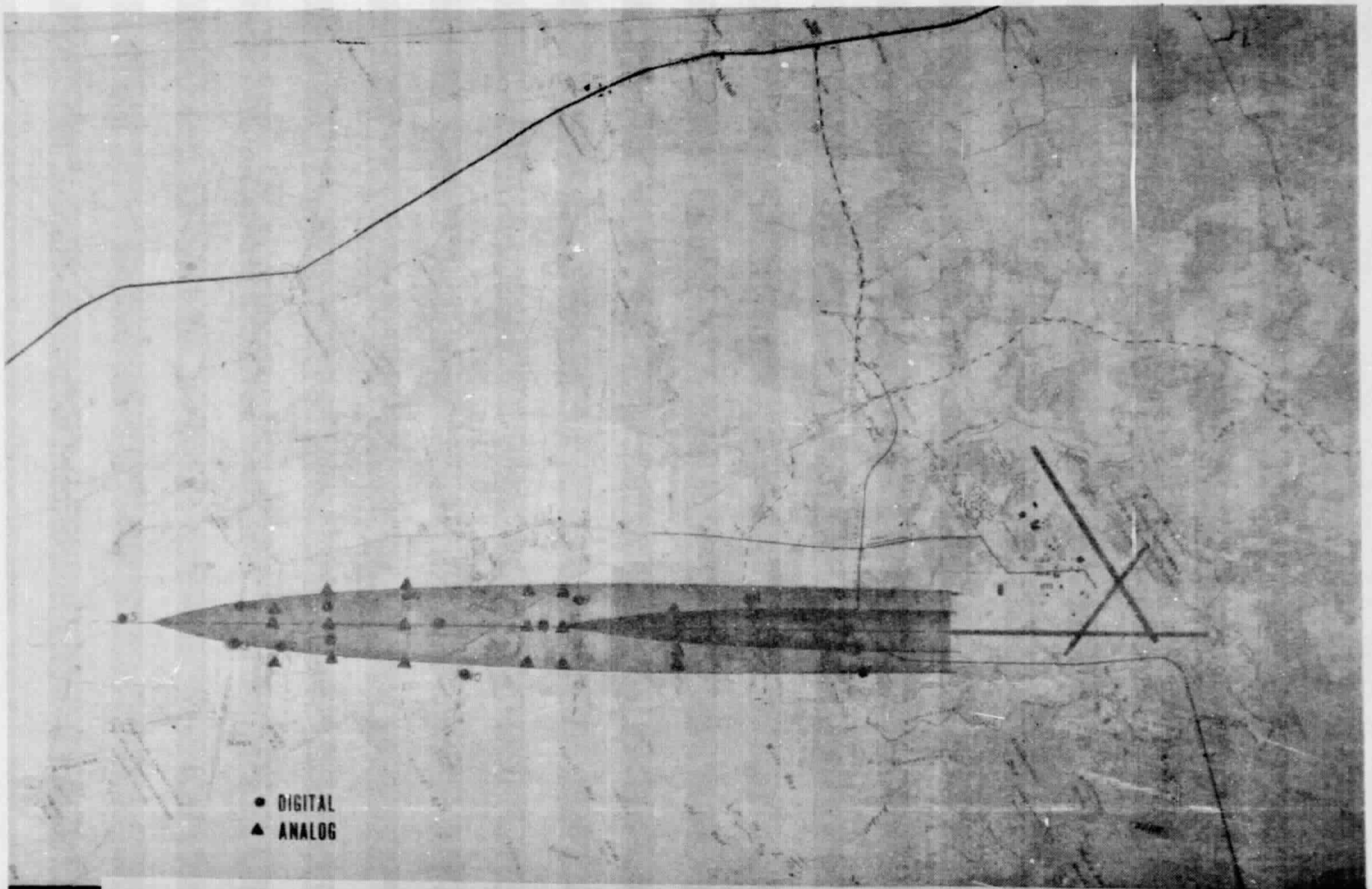


Figure 6.- Initial Noise Measurement Station Location for ROMAAR

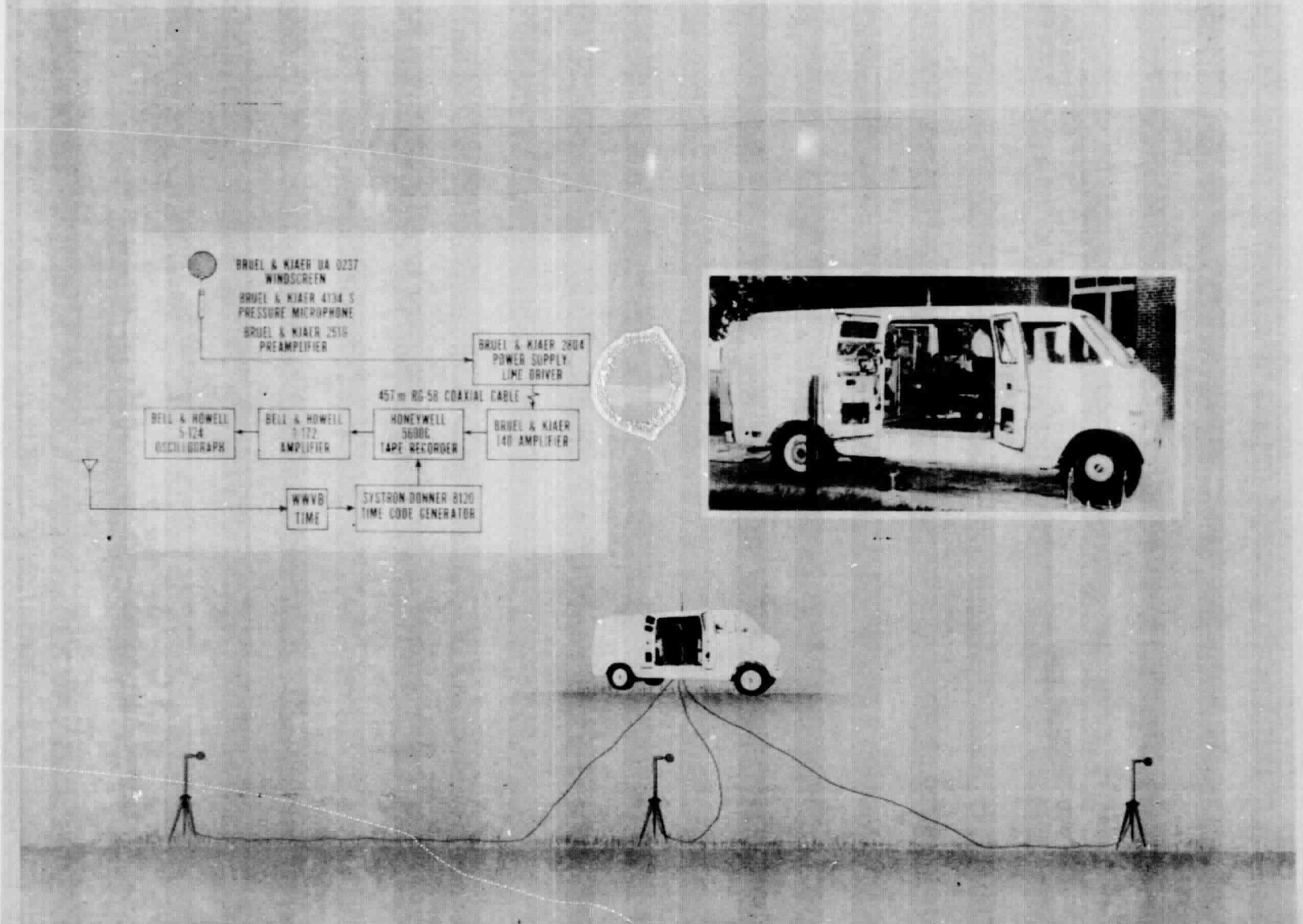
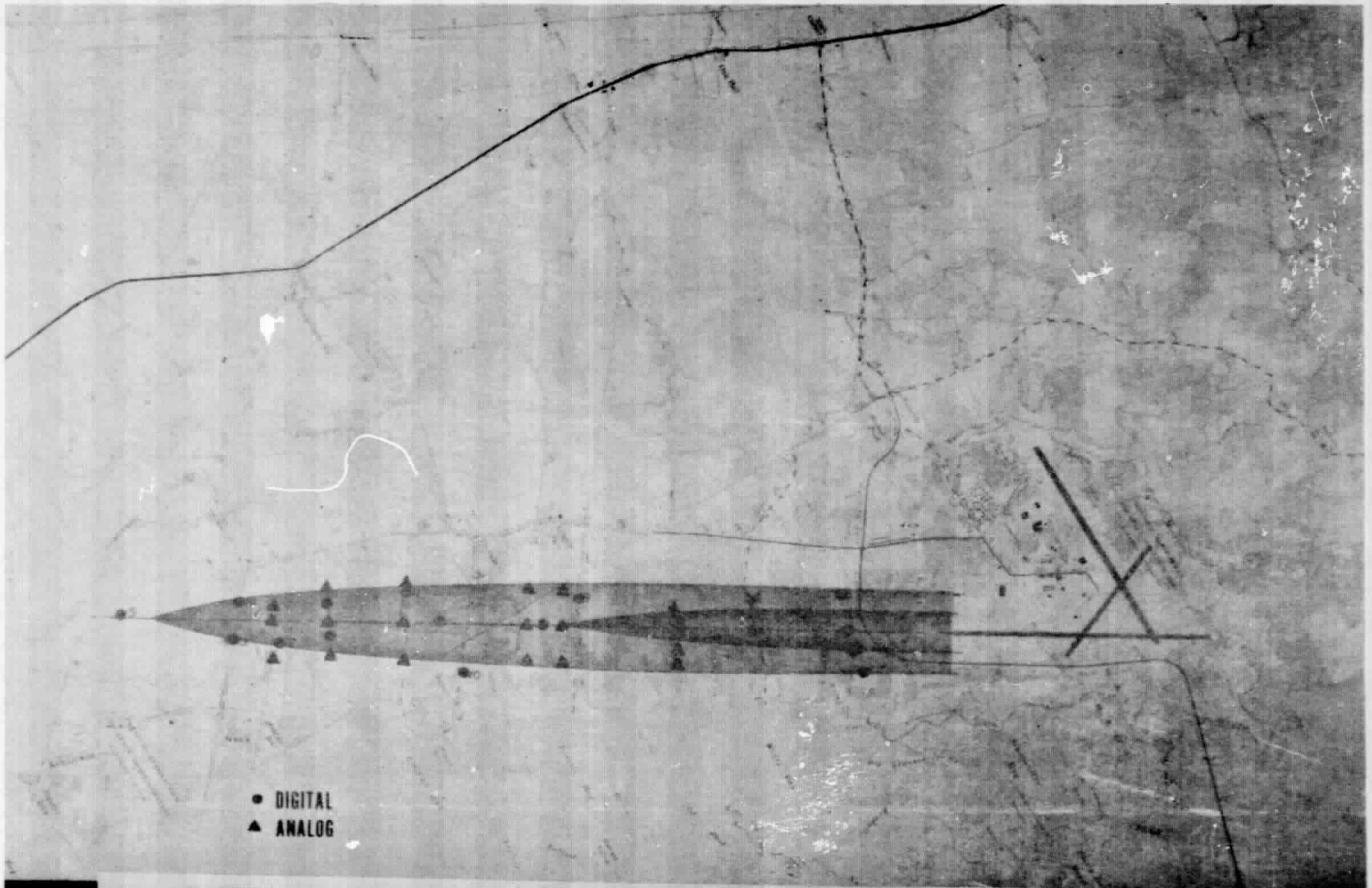


Figure 5. - Schematic and Photograph of the Analog Noise Measurement System.



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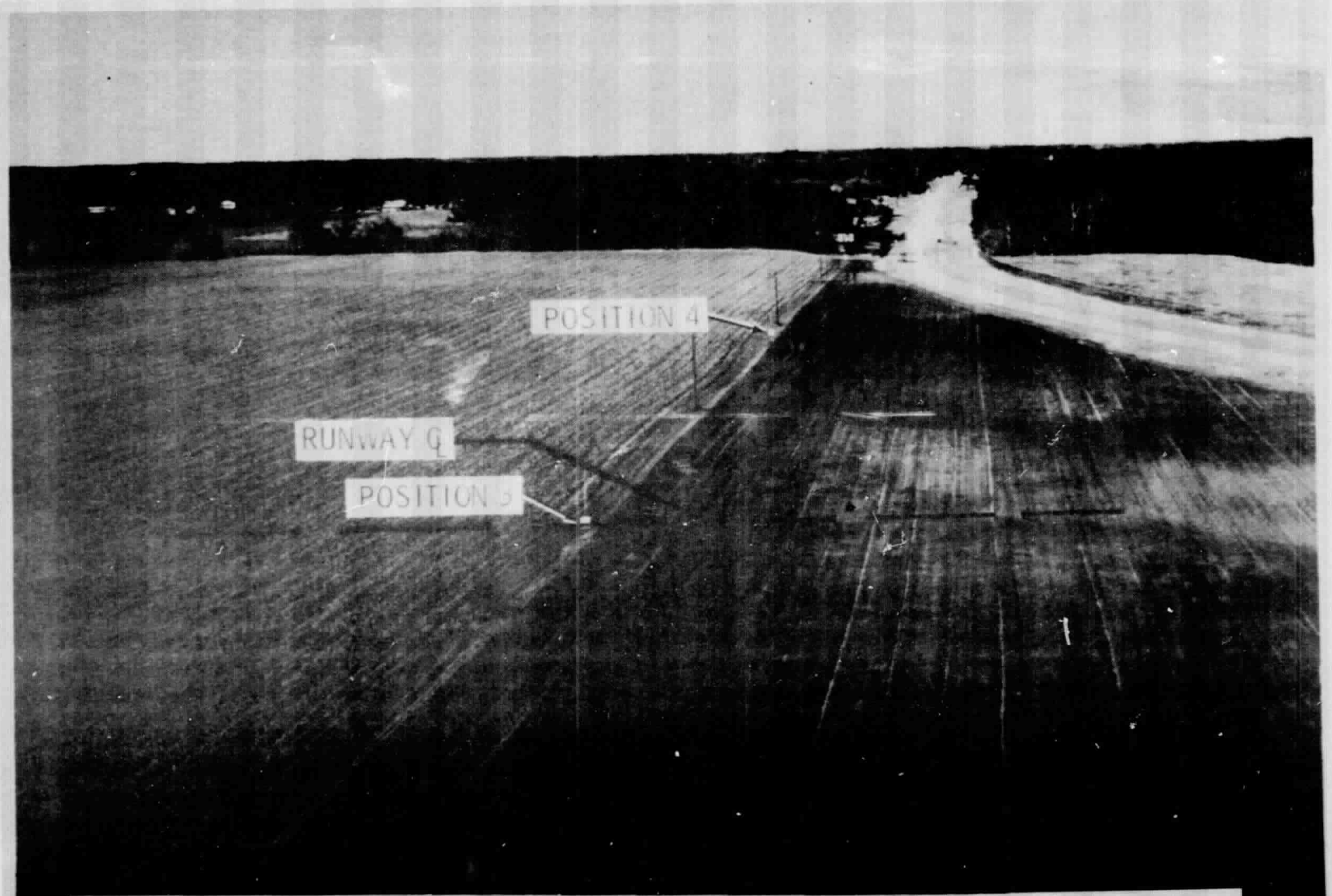


Figure 7. - Typical Digital Noise Measurement Site

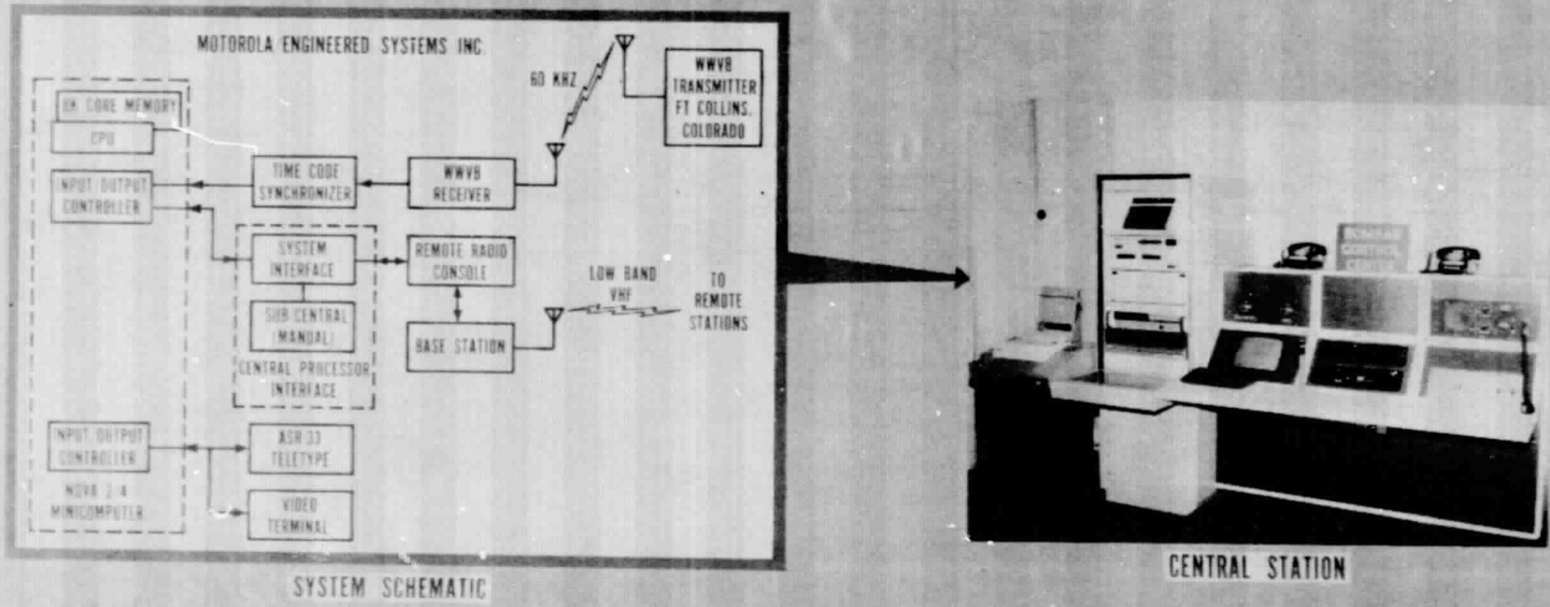


Figure 8. - Schematic and Photograph of the ROMAAR Central Station.

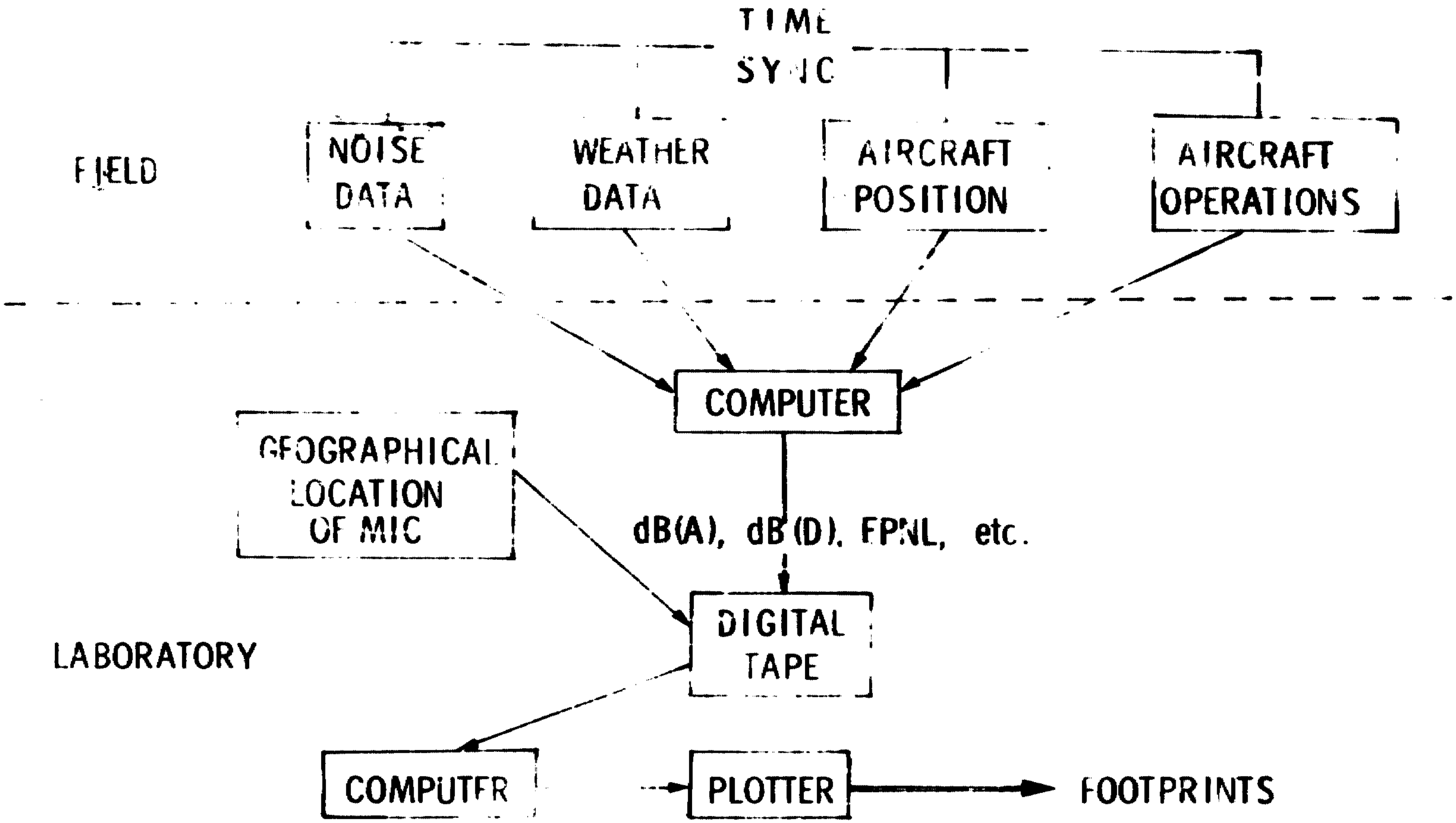
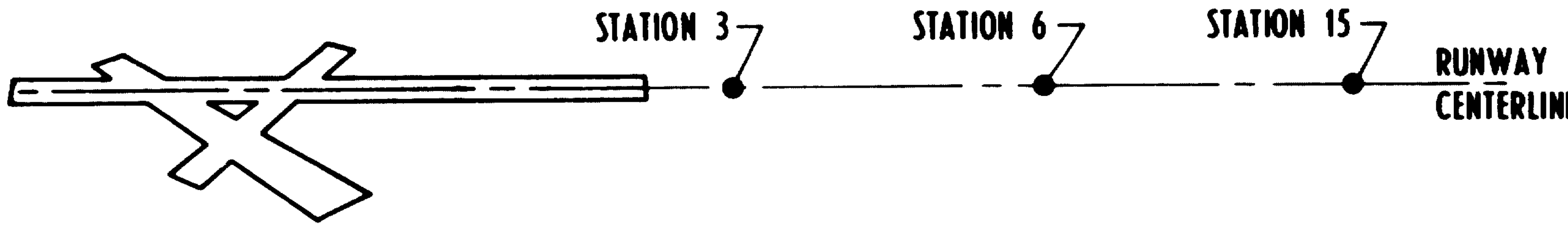


Figure 9. - Flow diagram for the ROMAAR data formatting and processing.



STATION	SYSTEM	dBA	TIME
3	DIGITAL	90.0	12:46:57.5
	ANALOG	90.4	12:46:58
6	DIGITAL	89.0	12:41:02
	ANALOG	89.8	12:41:02.5
15	DIGITAL	89.0	12:32:03.5
	ANALOG	89.7	12:32:04

Figure 10.- Comparison of Maximum dB(A)'s as Measured at Co-located Digital and Analog Noise Measurement Systems During the Flyover of a T-38A Aircraft (constant altitude flyover)

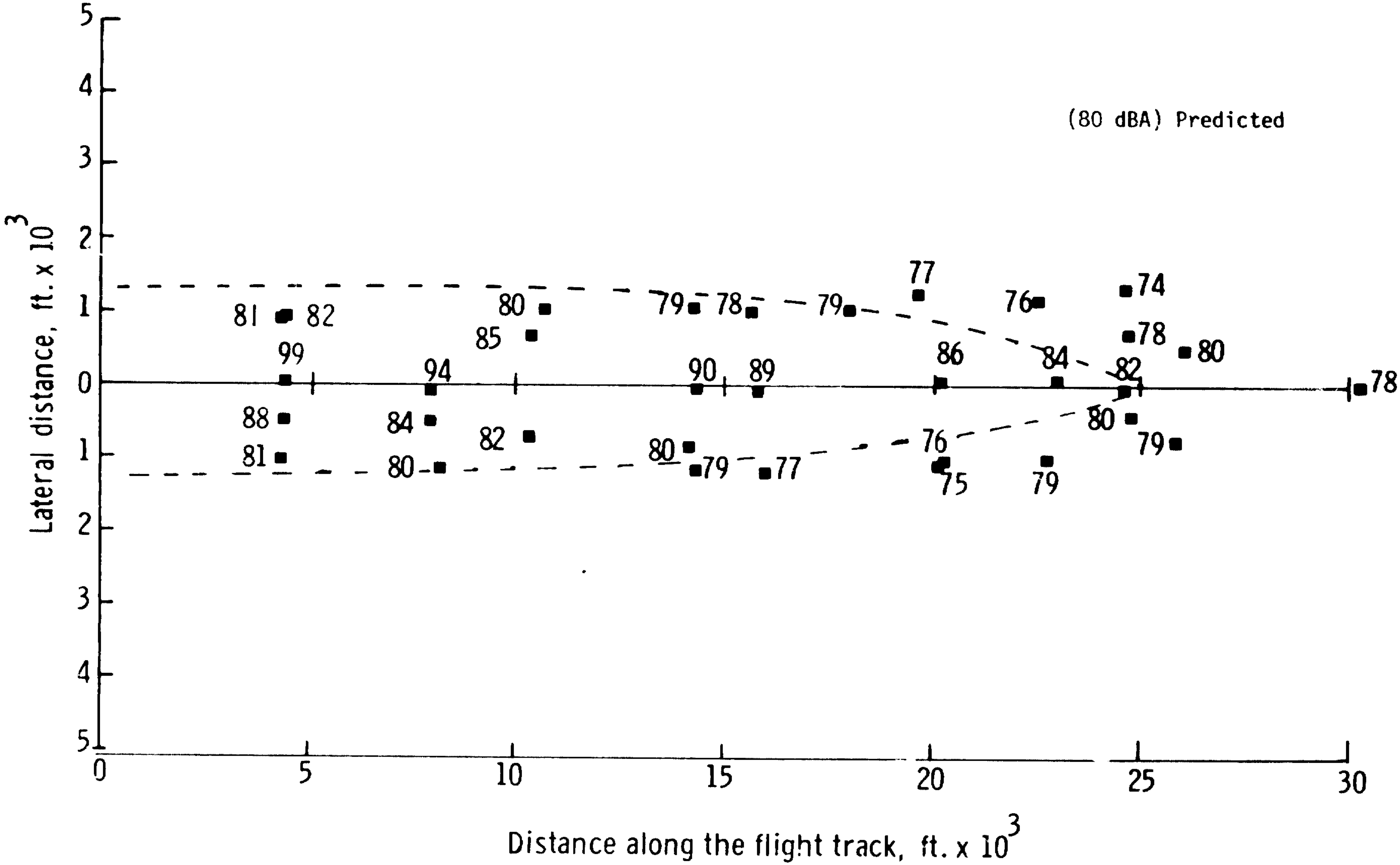


Figure 11. - ROMAAR Sites with Measured dBA Values for a Three Degree Landing Approach of a T-38 Aircraft (A Predicted 80 dBA contour is included)

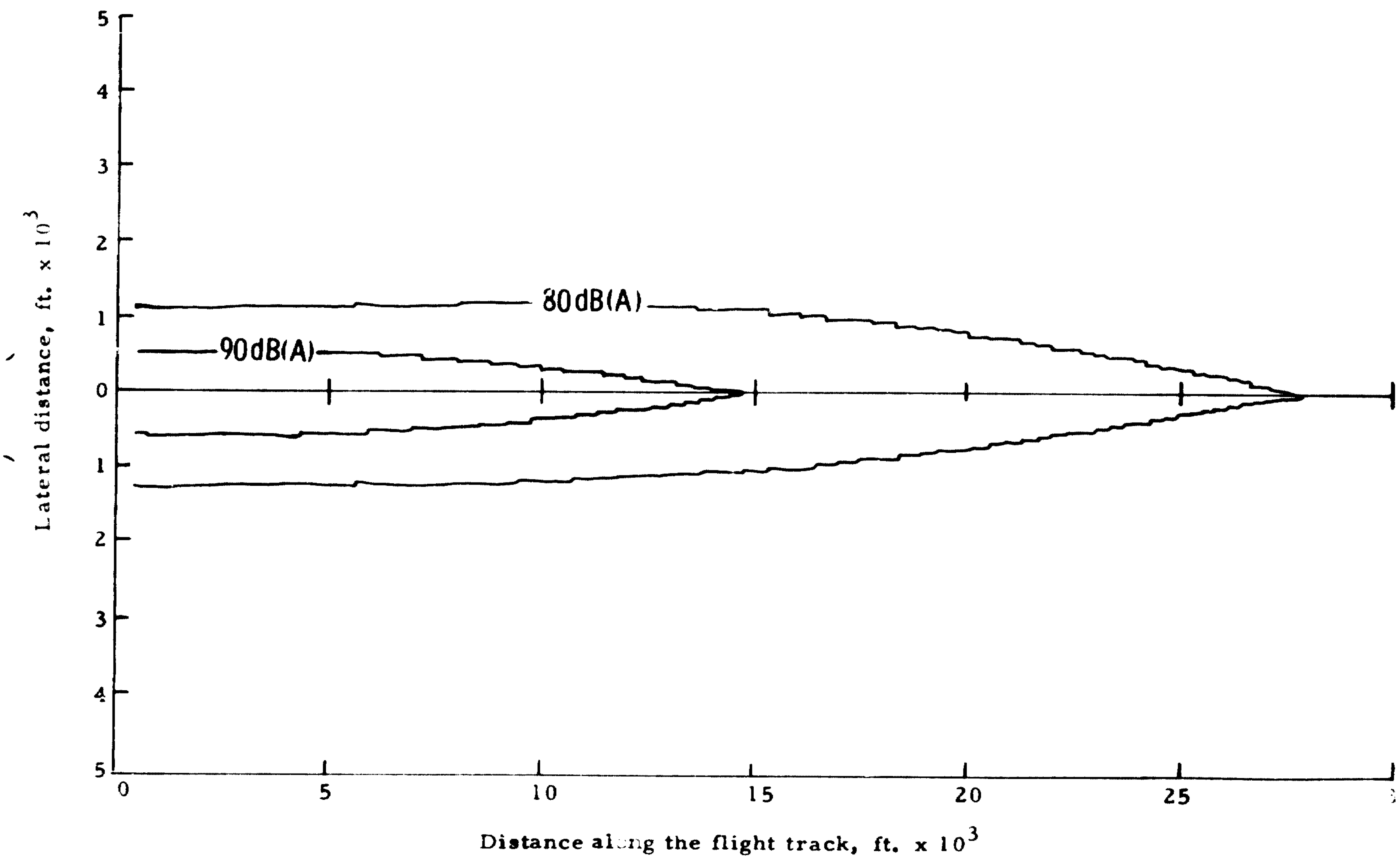


Figure 12. - Maximum dB(A) Footprints from Measurements during the Three Degree Landing Approach of a T-38 Aircraft